AGN FEEDBACK IN GALAXY GROUPS: THE CASE OF HCG 62

Myriam Gitti

(SAO-CfA, UniBO, OABO)

In collaboration with:
E. O'Sullivan (SAO-CfA), *S. Giacintucci* (SAO-CfA),
L. David (SAO-CfA), *J. Vrtilek* (SAO-CfA),
S. Raychaudhury (Univ. Birmingham), *P. Nulsen* (SAO-CfA)

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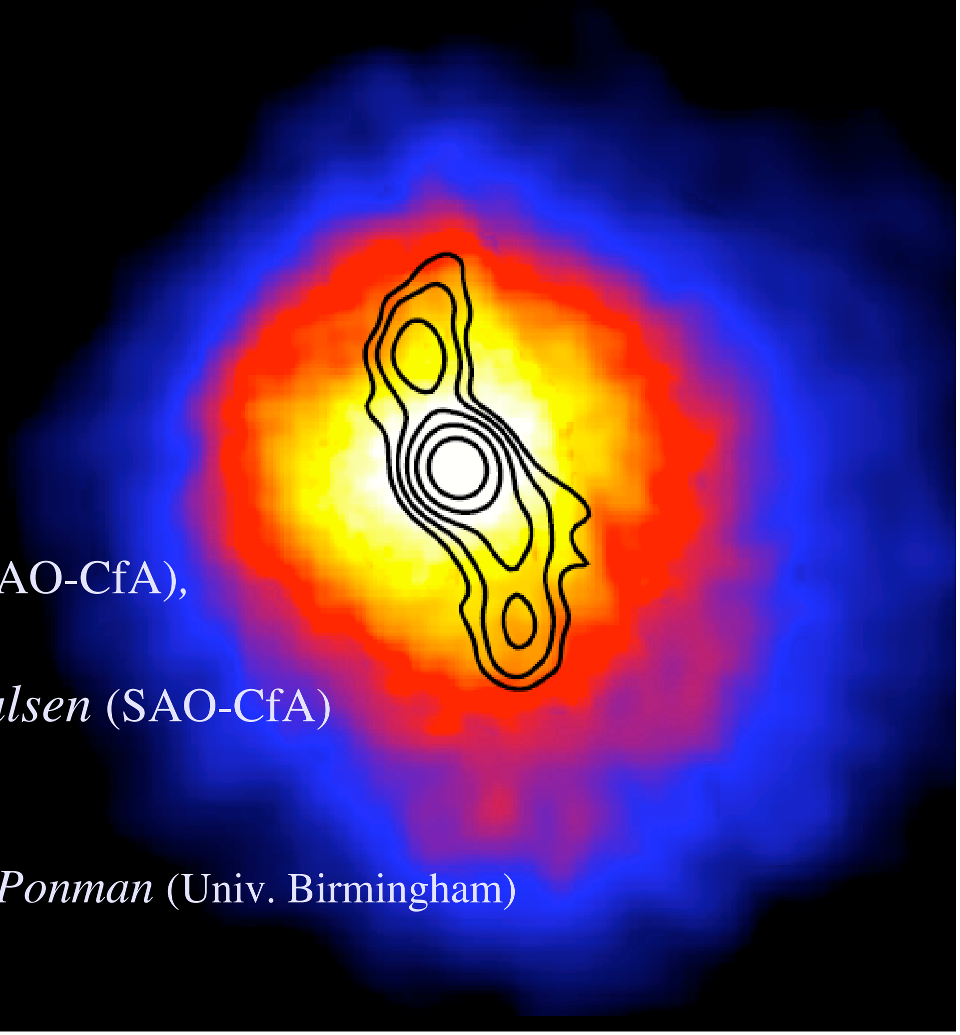


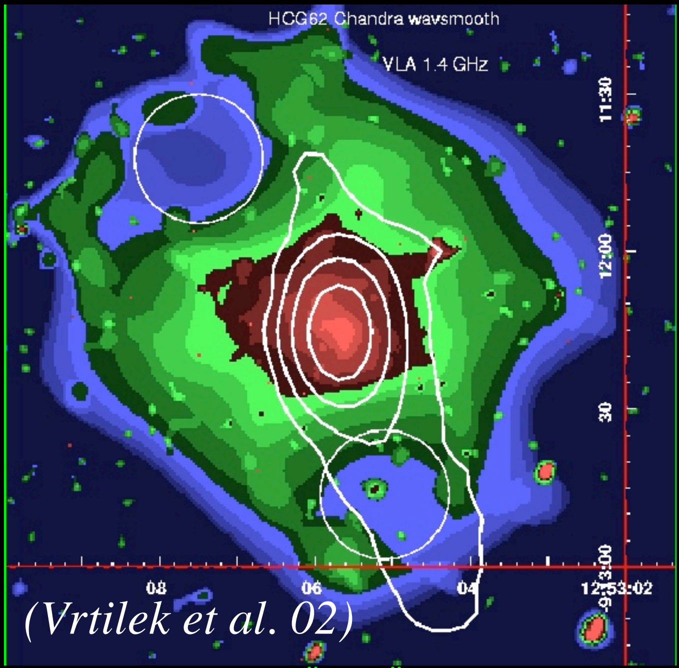
A project to combine X-ray and low-frequency radio data

Target selected by presence of X-ray/radio structure indicative of AGN interaction with hot gas

Group	z	$S_{1.4GHz}$ (mJy)	Log L_X (erg s^{-1})	*GMRT* 235 MHz	*GMRT* 327 MHz	*GMRT* 610 MHz	*Chandra*	*XMM*
UGC408	0.0147	1710	41.40	✓		✓	✓	
NGC315	0.0165	2010	41.57	✓		✓	✓	✓
NGC383	0.017	4862	42.72	✓		✓	✓	✓
NGC507	0.0165	99	42.95	✓		✓	✓	✓
NGC741	0.0185	1066	42.50	✓	✓	✓	✓	✓
HCG15	0.0208	25	42.25			✓		✓
NGC1407	0.0059	86	41.92	✓		✓	✓	✓
NGC1587	0.0123	132	41.53	✓		✓	✓	
MKW2	0.0368	385	42.32	✓		✓		✓
NGC3411	0.0153	38	42.51	✓			✓	✓
NGC4636	0.0031	78	41.71	✓		✓	✓	✓
HCG62	**0.0137**	**5**	**43.20**	**✓**		**✓**	**✓**	**✓**
NGC5044	0.009	36	43.09	✓	✓	✓	✓	✓
NGC5813	0.0066	15	42.06	✓		✓	✓	✓
NGC5846	0.0057	21	42.04			✓	✓	✓
AWM4	0.0318	608	43.30	✓	✓	✓	✓	✓
AWM5	0.0348	50	43.20			✓	✓	
NGC7626	0.0114	860	42.05	✓	✓	✓	✓	✓

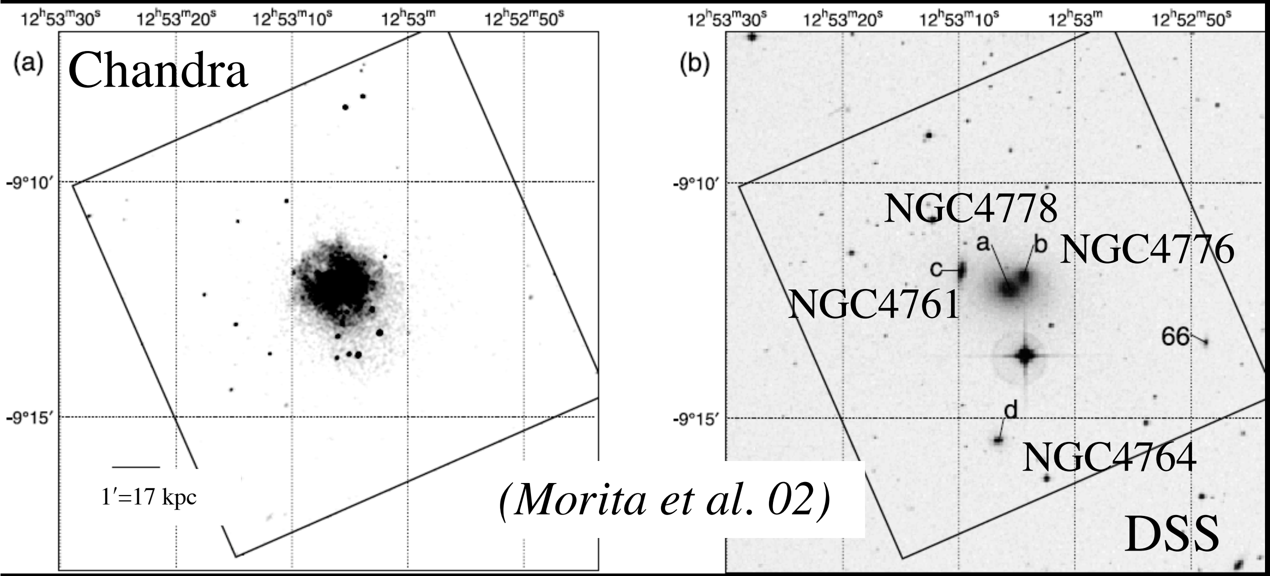
HCG 62 (z = 0.014)

- One of the most intrinsically luminous of the 100 Hickson compact groups: $L_X \approx 10^{43}$ erg s^{-1}
- $M_{gas} \approx 10^{12}\ M_{sun}$ within ~20′ *(Ponman & Bertram 93)*
- VLA 1.4 GHz : S = 6.6 mJy
- Very clear, small X-ray cavities (first detection in a galaxy group)



(Vrtilek et al. 02)

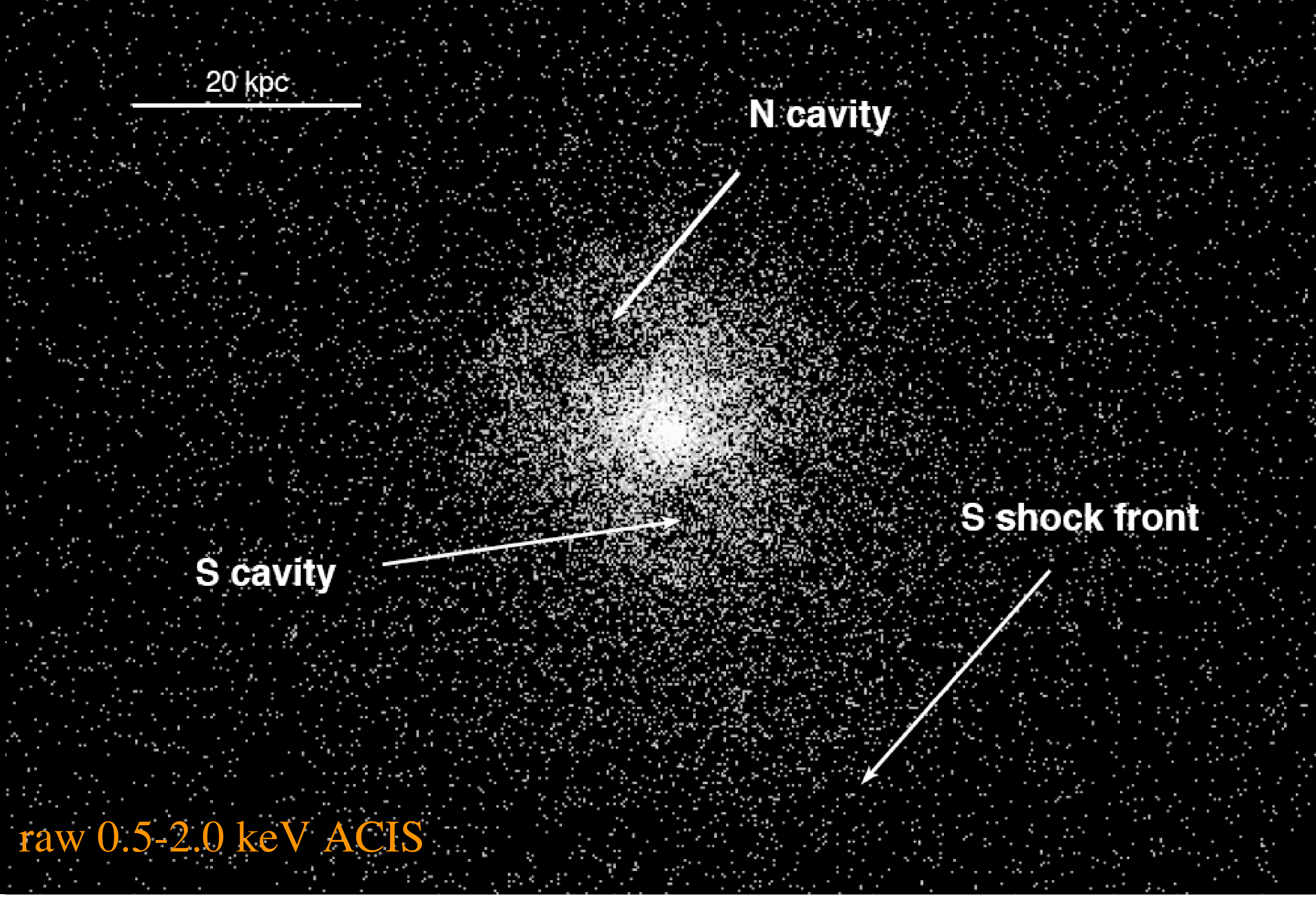
beam=18″×12″
lowest contour at 0.3 mJy/beam



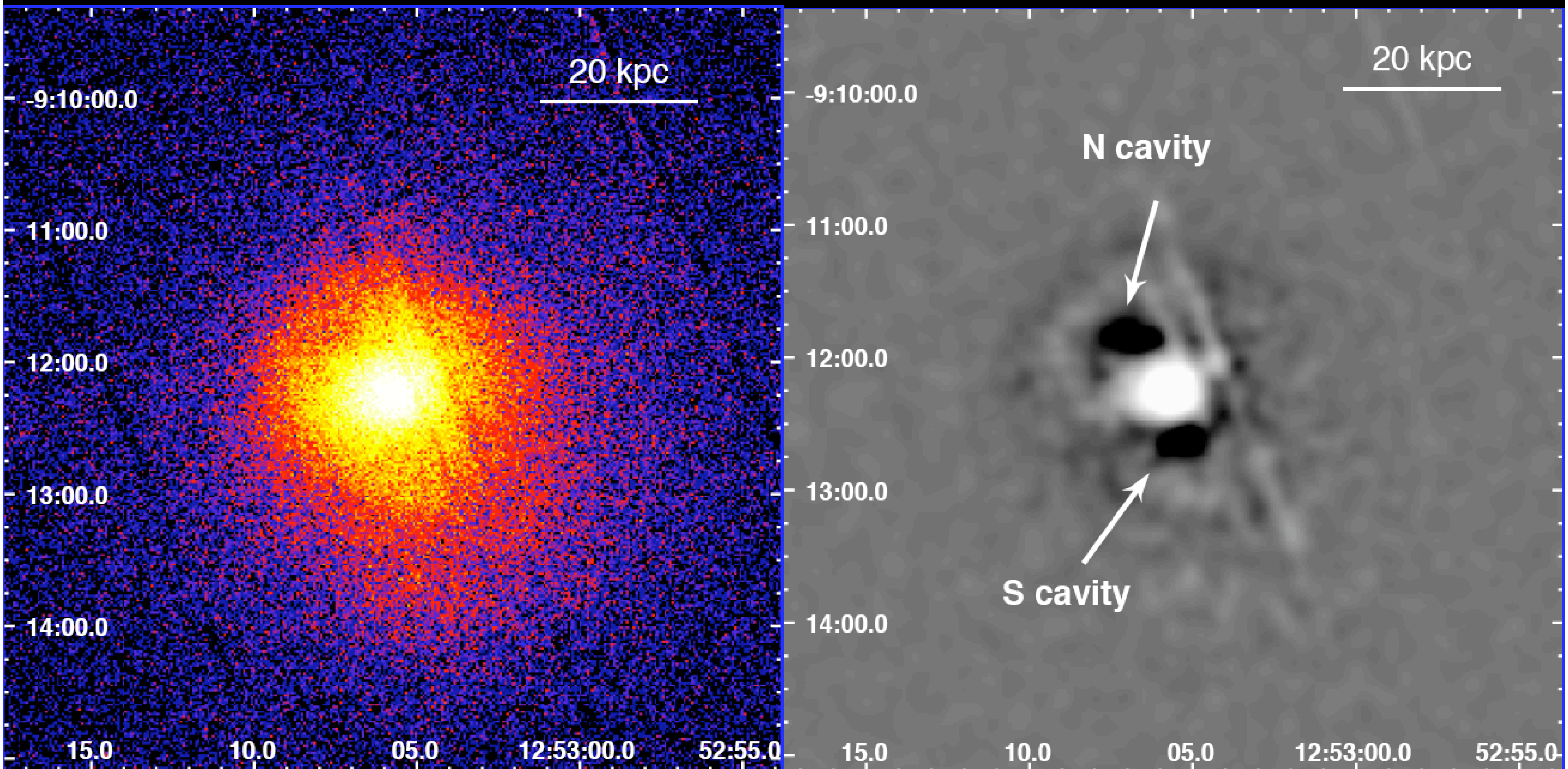
(Morita et al. 02)

- 63 galaxies within 50′ *(Mulchaey et al. 03)*
- central region dominated by 4 early-type galaxies
- NGC 4778 possibly interacting with NGC 4761 *(Spavone et al. 06)*

X-RAY DATA: *CHANDRA* 50 ks (2000)



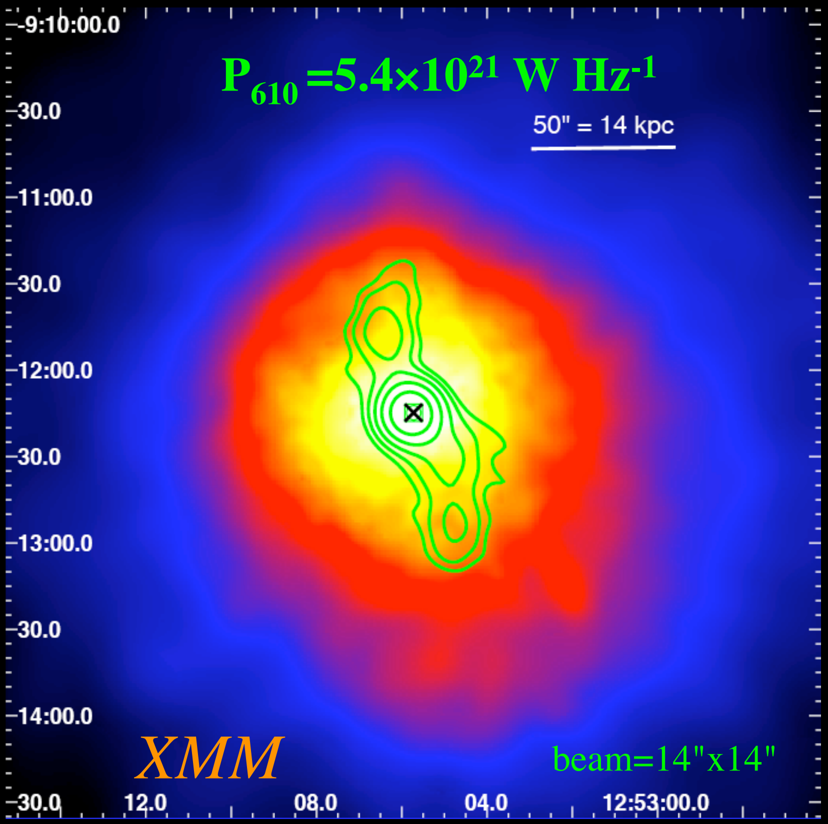
X-RAY DATA: *XMM* 90 ks (2007)

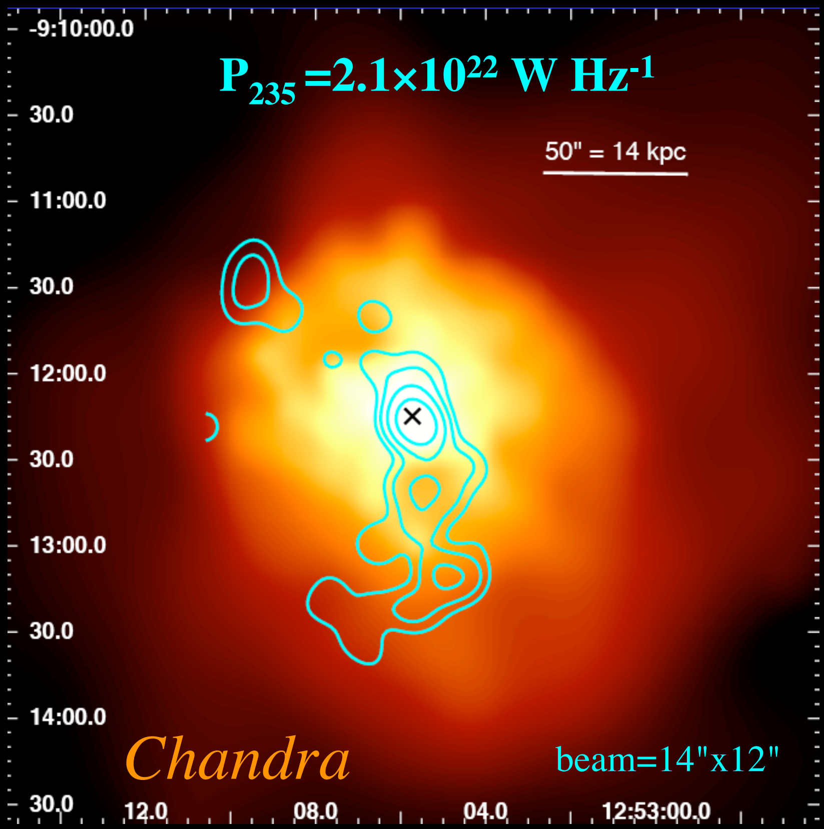


mosaic 0.5-2.0 keV MOS+PN

Unsharp masked image

(new!) RADIO DATA: *GMRT* 2h (2008)





610 MHz:

r.m.s. = 65 μJy/beam

S = 12.8 mJy (6.9 mJy core)

$\alpha^{235}_{610} = 1.42$

235 MHz:

r.m.s. = 230 μJy/beam

S = 49.6 mJy (15.1 mJy core)

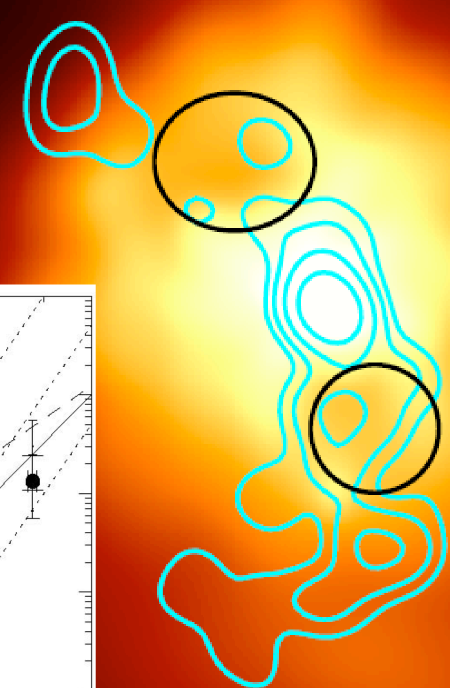
(Giacintucci et al., in prep.)

X-RAY / RADIO INTERACTION

– Energy budget –

GMRT @235 MHz

Chandra 0.5-2.0 keV



$$E = \frac{\gamma p V}{\gamma - 1}$$

P_{cav} =3.9×10^{42} erg s^{-1}

L_{ICM}=1.8×10^{42} erg s^{-1}

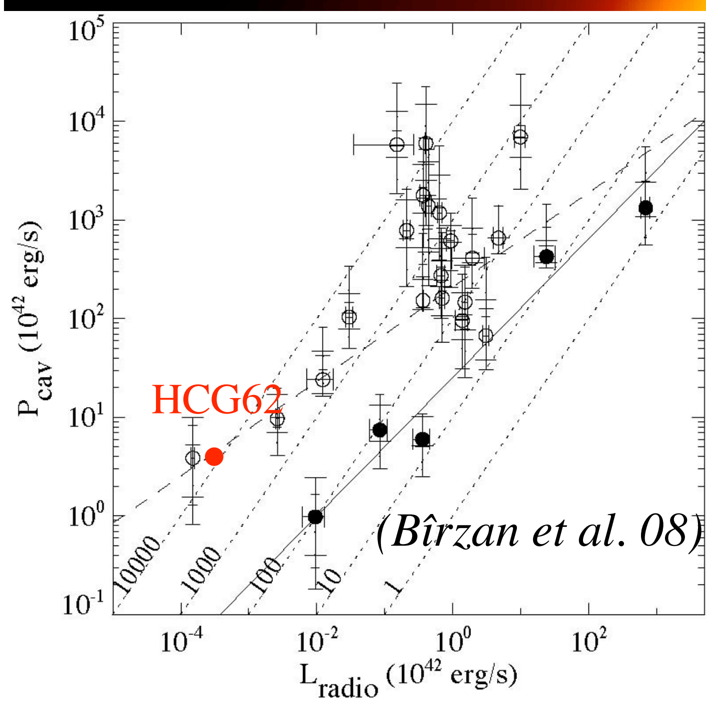
(Rafferty et al. 06)

The AGN outburst is currently supplying about twice the power lost by radiation within the cooling region

$L_{[10MHz\text{-}10GHz]}$ = 4×10^{38} erg s^{-1}

The radio luminosity is much less than the mechanical power

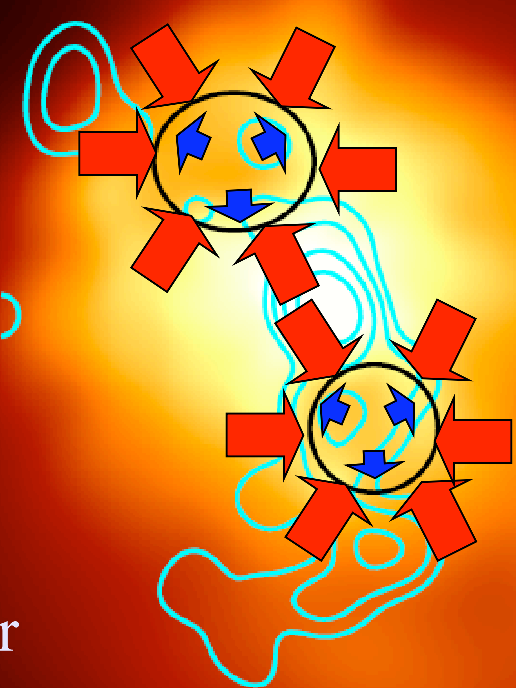
⇒ radiative efficiency ~ 10^{-4}



X-RAY / RADIO INTERACTION

– Pressure –

With “revised” (γ_{min}=100) equipartition *(Brunetti et al. 97)* the cavities are closer to pressure balance than are with standard equipartition



$$E_{pr} = k\, E_{el}$$

k = [6-27] required for pressure equilibrium
→ “light” **hadronic jets**

($k_{standard}$ ~ few hundreds)

(work in progress…)

Cavity N:

$B_{eq,rev}$ = 4 μG

P_X / P_{radio} ~ 4

[P_X / $P_{eq,standard}$ ~ 13]

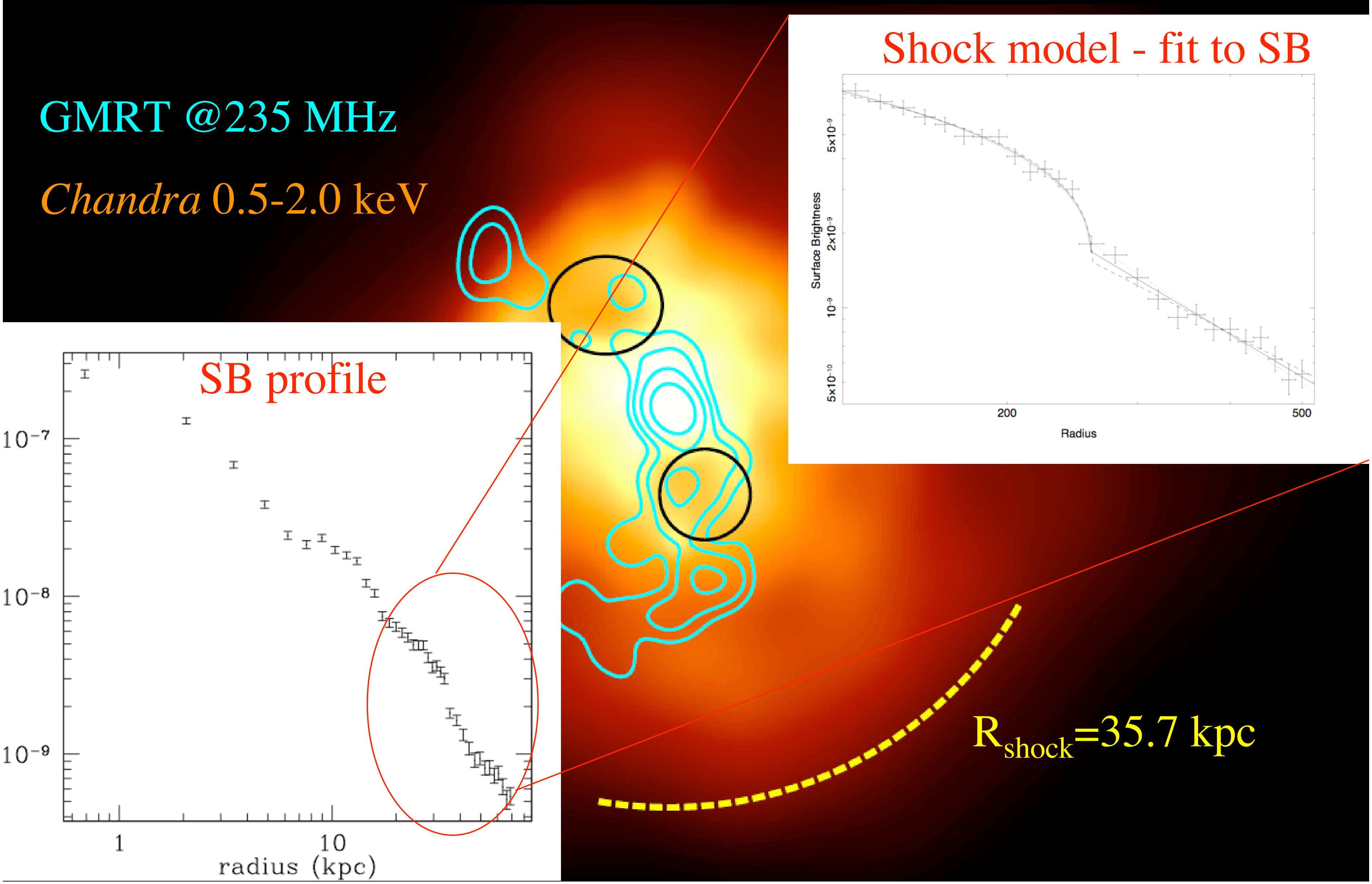
Cavity S:

$B_{eq,rev}$ = 7 μG

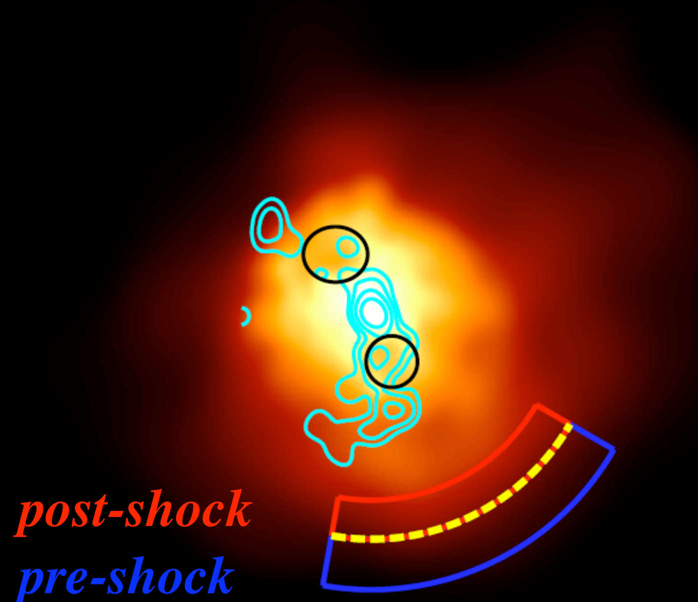
P_X / P_{radio} ~ 2

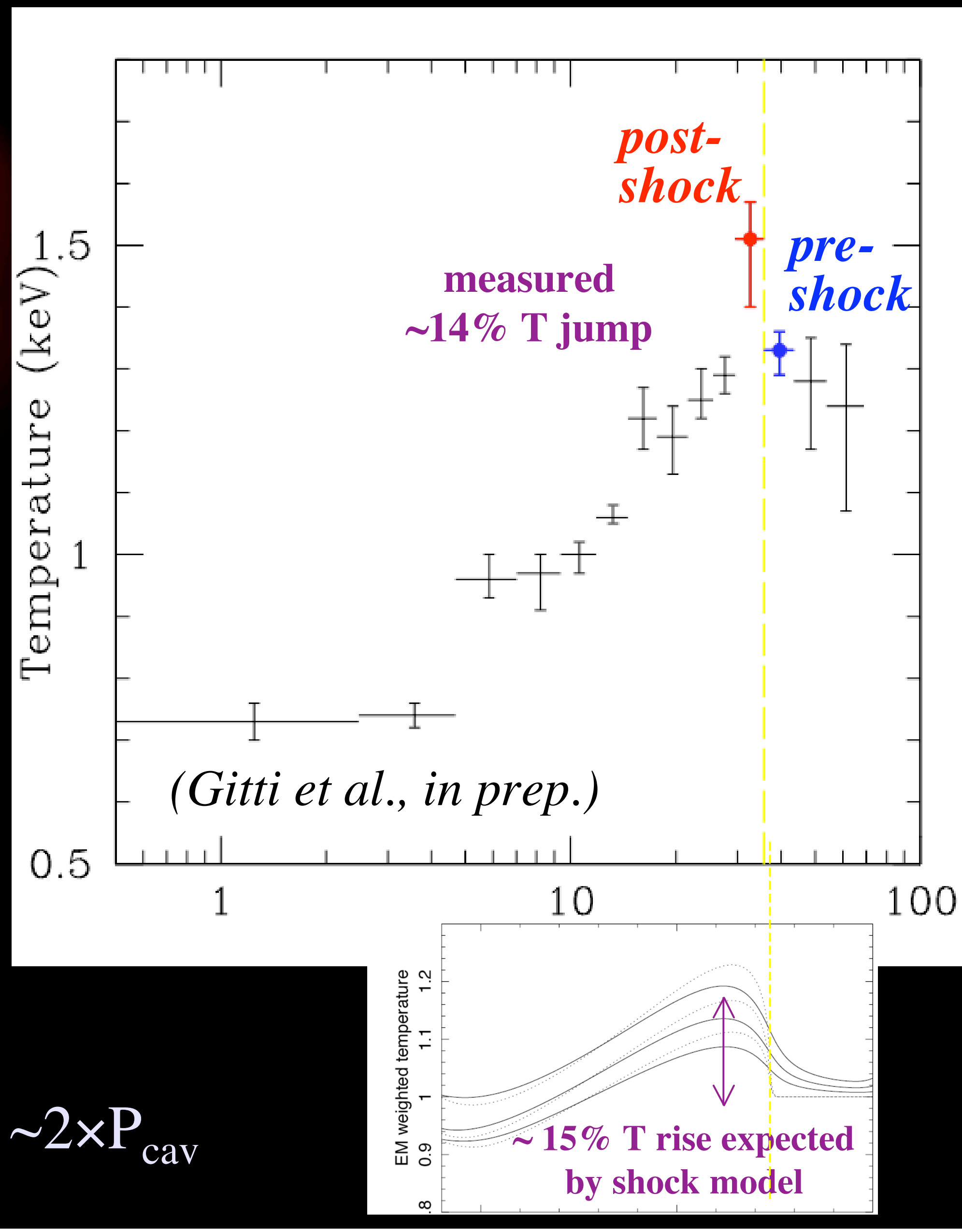
[P_X / $P_{eq,standard}$ ~ 8]

SHOCK FRONT – SB profile



SHOCK FRONT – T profile

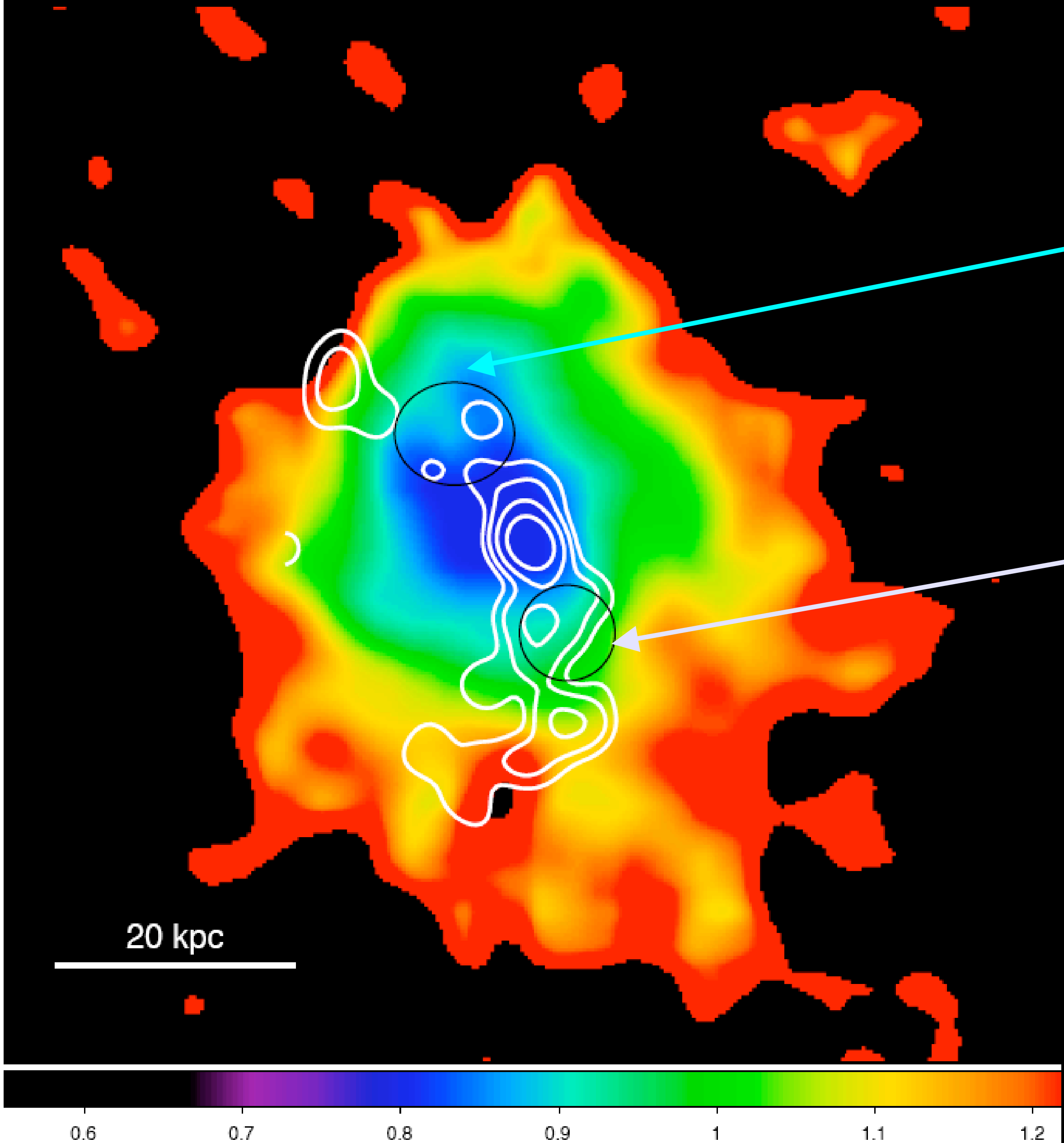




Shock model properties:

- Mach = 1.45
- Energy = 6.2×10^{57} erg
- Age = 2.7×10^{7} yr
- Power = 7.3×10^{42} erg s^{-1} $\sim 2\times P_{cav}$

TEMPERATURE MAP



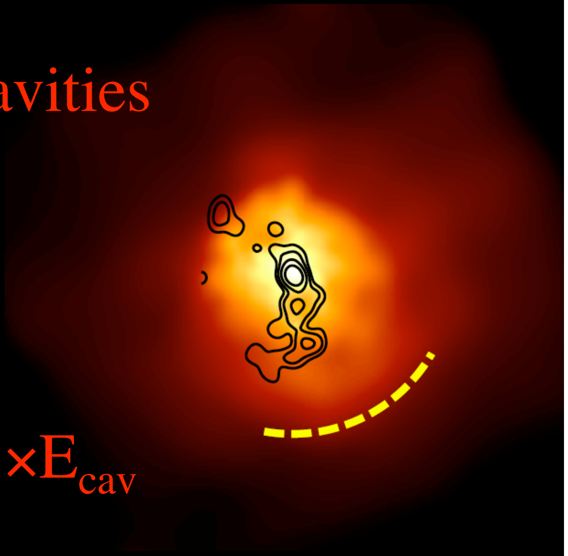
Cool region along the N cavity limbs

why not in the S one?
maybe heated by the passage of the shock
→ asymmetric shock?

XMM hardness ratio map
(*Chandra* consistent)

Summary on HCG 62

- Strong example of the benefits of a combined X-ray/radio approach to the study of AGN feedback
- Low-frequency radio emission detected in the cavities
- Very low radiative efficiency ~ 10^{-4}
- "Light" hadronic jets
- Detection of shock front with M ~ 1.45, $E_{shock} \sim 3 \times E_{cav}$
- Total energy in shock + cavities ~ 8×10^{57} erg



(Gitti, O'Sullivan, Giacintucci et al., in prep.)